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Urgent need for new approach to energy policy: The case of Finland

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ABSTRACT

The process of climate change is already under way and is a serious threat facing the planet. Our response to this threat will irrevocably transform the energy sector and the priorities within it. The trend in emissions over the next decade will largely determine whether the process of climate change can be kept at a moderate level. This literature-based study focuses on Finland as an example case. Oil price fluctuations, economic development and changes in consumer values and attitudes are key forces that will drive change in the energy sector. A greater diversity of energy sources is vital if we are to avoid a catastrophic warming of the climate. The use of renewable energy sources must be increased, and the efficiency of producing, transmitting and distributing energy must be improved. The energy sector must also exploit the potential of nuclear energy, wind, solar and hydro power, afforestation measures, biomass resources, carbon capture and storage (CCS) technology and the nano-bio sector. National policies and measures must be set out in detail and global cooperation enhanced. The presence and impact of factors that impede the work to curb climate change must also be taken into account in energy strategies if these strategies are to be successful.

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1. Introduction

The ongoing process of climate change and the implications of this threat are one of the most challenging problems facing the world today. There is a general consensus that global warming is a consequence of anthropogenic greenhouse gases [e.g. 1]. About 80% of these greenhouse gases are from the production and consumption of energy. Globally, approximately 40% of the average total energy consumption is related to the construction and use of buildings [2].

Most of the world's energy is produced and consumed in a manner that cannot be sustained using current technologies and with total consumption on the increase. Countries will have to focus on improving the efficiency of energy production, transmission, distribution and use [3].

To bring together energy needs and the right technologies, a considerable amount of research on these technologies is still required [4–6]. Existing alternative energy sources must also be

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exploited [7–10]. The scale of energy consumption and of potential energy savings is so great [11] that the research needed must reach across a range of disciplines. The transfer towards a sustainable energy system [12] must also take into account the fact that energy needs are concentrated at specific consumption points; such a system could therefore include a strong focus on distributed energy production [13]. There is also a heightened need for international collaboration [e.g. 4–6,11].

Energy, the environment and economic and technological development are all inextricably linked with each other [14]. Energy is a vital ingredient in socio-economic development and in economic growth [15]. The world's population and the global economy are growing fast, especially in the developing countries, and along with this the demand for energy is rising rapidly as consumer demand for goods and services grows. Total global energy consumption is increasing inexorably [16]. Today's affluent societies are very strongly reliant on energy to keep their buildings and services running [17]. The onus is placed on energy producers and governments to ensure that good quality energy is produced on a continuous basis and at affordable prices in order that societies can grow while adhering to sustainable development principles [18].

Energy and environmental issues are closely interwoven with global and national economic circumstances. Indeed, the costs and the risks associated with climate change have risen to the fore in the debate on greenhouse gas emissions, and the rise in energy and raw material prices has been a driving force in the market for clean energy technologies. These prices will, in the short run, be affected by factors such as the situation in the Middle East, the global economy and the production policy of the Organization of Petroleum Exporting Countries (OPEC). The substantial rise in the world market prices of oil, coal and natural gas and the high price of emission permits under the European Union's emissions trading system have led to a significant change in the relationship between the prices of fossil energy forms and renewable energy—in favour of the latter [17].

The declared aims of energy saving include reducing the rate of depletion of the world's non-renewable energy reserves, cutting energy costs, decreasing energy dependency, achieving self-sufficiency in energy and ensuring that energy supplies are sufficient. Energy savings can be sought at both ends of the chain: in all areas of energy production and energy consumption [19]. The range of different savings measures is varied and complex, as the production, transfer and consumption of energy are all closely interrelated. In designing measures affecting energy production, for example, it is also necessary to consider the impact of a saving in one area on savings in other areas. The full impact of an individual energy saving is therefore not easy to measure. The combined effect can, on occasion, also be greater than the sum of the individual effects. Energy savings are not simply measurable as an amount of unconsumed energy.

The aim of the present study is to analyse the changes occurring in the energy sector and their effects, and to look at various future scenarios. At issue is an elaborate web of effects and counter-effects [20]. The challenge is to introduce sufficiently concrete policies and measures to curb climate change and to ensure that these are based on a full understanding of the multifaceted nature of energy production and consumption. This study is based on a review of the literature and focuses on Finland as an example case.

2. Climate policy

2.1. International climate treaties

Global climate policy seeks to establish targets and a framework within which national strategies for controlling climate change can be determined. Internationally, agreement was reached on restricting emissions to a sustainable level back in 1992, in the United Nations Framework Convention on Climate Change (UNFCCC) [21], which has been signed by almost all nations of the world, including the United States. This agreement is also known as the Climate Convention.

The ultimate goal of the Climate Convention is to stabilise the concentration of greenhouse gases in the atmosphere at a level that would avoid dangerous changes in the climate as a result of human activities. This target concentration would have to be achieved sufficiently quickly in order that the ecosystem can adapt naturally to the changing climate, that any threat to food production can be avoided and that the global economy can accommodate sustainable growth. The latter economic consideration is a cornerstone of climate policy: not only will the costs of mitigating climate change have a negative impact on economic growth potential, but without huge investment sustainable development will not be possible.

The European Union (EU) has proposed that the average global temperature rise should be limited to an increase of two degrees Celsius above that of pre-industrial times, in order that the detrimental effects of climate change can remain within tolerable limits. The EU is committed to reducing emissions by at least 20% by 2020, and by 60–80% by 2050. According to the Intergovernmental Panel on Climate Change (IPCC) [22], achievement of the two degree goal will require that the world's greenhouse gas emissions be reduced by 50–85% by 2050. Operating under the United Nations, the IPCC is a scientific body set up for the purpose of publishing impartial information on climate change.

This classic target of limiting global warming to two degrees has been the goal of international climate policy for a decade already, based on the belief that this will prevent 'dangerous' climate change. The target has also been criticised [23] and other proposals presented instead, among them the suggestion that the industrialised countries should reduce their emissions by as much as 70% by 2020. It has also been proposed that the longer term goal should be zero emissions. The argument is that significant new data on the progress of climate change and on the accelerating rate of its effects has emerged in the last 2 years. The latest IPCC report [22], regarded as the scientific basis for climate policy, was published in 2007 and does not therefore take account of the latest research results. For example, the rate at which the Arctic ice cap is melting and the volume of methane emissions from the permafrost-covered tundra have in recent years exceeded most estimates.

The Kyoto Protocol, adopted in 1997, was the first legally binding international treaty containing quantified emissions reduction targets. Under the Protocol, the industrialised countries agreed to reduce their greenhouse gas emissions by a total of 5.2% from the 1990 level by the target period of 2008–2012. Built on the work of the UN Climate Convention, the Kyoto Protocol covers six greenhouse gases: carbon dioxide, methane and nitrous oxide, and three industrial compounds or groups of compounds (HFCs, PFCs and SF_6). If a signatory state fails to reach its target, it must make up the shortfall in the next target period as well as achieving a further 30% reduction. The country in question would also be subject to a suspension of its ability to sell credits [24]. Future climate policy is therefore of huge significance, as the emissions reductions that will be required from industrialised countries under the Kyoto Protocol are a far cry from those required under the two degree target. It is also essential that the developing countries should already be looking for solutions for exploiting renewable energy sources and for making the fullest use of the potential for energy efficiency. The industrialised countries have a responsibility and obligation to provide developing countries with the means to develop using sustainable energy production.

The Conference of the Parties (COP) to the Climate Convention convenes annually. At its latest gathering, in 2008, the COP 14

focused on how the different negotiating tracks could be advanced to a point where as many nations as possible could be included in full [25]. The EU has emphasised the importance of the emission permit market in future solutions. According to the EU, the country-specific targets for the industrialised countries must be based on figures for emissions reduction potential calculated in accordance with a 'top down' approach, i.e. on a per capita basis. To ensure that the need for emissions reductions is understood by all members of the public, it will be important to focus on the essential aspects of the arguments. In Finland, per capita emissions would be boosted by the cold winters and the long distances travelled, but would be kept in check by the energy-intensive paper and steel industries. Japan, on the other hand, made a strong case to the COP 14 for the need to examine first the realistic scope for reduction measures in different economic sectors and to set targets only when this is done. The next COP meeting – the COP 15 in December 2009 – will be critical and expectations are high: a global and comprehensive climate treaty for the period beyond 2012, which is the year the first Kyoto Protocol commitment period expires.

Differences between national climate policies would appear to depend on whether or not the country in question has ratified the Kyoto Protocol. Countries that have done so seem to be distinctly more interested in the environmental and political dimensions of climate change, and to be pursuing more efficient and desirable energy solutions [26]. The opportunity exists, at least in theory, for each and every country to sign the Kyoto treaty.

A successor is now being urgently sought to the 1997 Kyoto Protocol, which has not only built on the work of the Climate Convention but also experienced many setbacks along the way. A successor is essential in order that universally agreed rules can be established for restricting greenhouse gas emissions in the period beyond 2012. If a consensus is achieved, the impact on the operations of the power-generation industry and energy-intensive industries will be considerable. Energy saving and energy production from renewable sources would become increasingly more competitive options. The alarming research results of recent years concerning the acceleration of climate change and the seriousness of the threat have already spurred the international community to act with a sense of urgency. One example of this new sense of purpose is the ASEM Declaration on Climate Change approved at the Helsinki meeting of ASEM, the cooperation forum for European and Asian states, in 2006.

The considerable uncertainties involved in assessing climate change and its impacts make it impossible, in practice, to determine a specific level of greenhouse gas concentrations that can be accepted. However, political decision-making at international level is always about estimation and judgement [27]. Such estimations and judgements will form the basis for consideration of the scope for mitigating and adapting to climate change and the costs of doing so, and also the socio-economic costs and benefits of climate change and efforts to control it. The implications of climate policy for other international treaties and institutions, such as the World Trade Organisation (WTO), must also be taken into account [28].

2.2. Finland's climate and energy policy

A special focus of this study is the energy sector in Finland. In Finland and at EU level there are many different projects aimed at improving the state of the environment. To ensure that targets can be reached it is necessary to introduce appropriate legislation. The EU's environmental policy forms the basis for Finnish efforts to influence climate change and for Finnish legislation on the energy sector. The European Climate Change Programme (ECCP), which operates under the Commission, has the task of investigating the possible policy options and the EU's potential for meeting the Kyoto targets.

Table 1
Total consumption of energy in Finland, 2008, preliminary estimates [29].

Source	Consumption (PJ)	Per cent of total energy consumption (%)
Net imports of electricity	42	3
Water and wind	56	4
Peat	84	6
Coal	140	10
Natural gas	154	11
Nuclear	238	17
Wood fuels	294	21
Oil	350	25
Others	28	2
Total (estimates)	1400	100

Finland, for its part, has already made a number of key energy policy decisions, and in 2008 its carbon dioxide emissions from energy production and consumption fell by 12.5%, and its use of renewable energy was up by 5% on the previous year's figure. Table 1 below illustrates Finland's preliminary estimates energy consumption by sector in 2008. [29]

Finland's Long-Term Climate and Energy Strategy was approved by the Government in November 2008 [17]. The strategy sets out climate and energy policy measures in some detail for the period to 2020, and in broad terms up to 2050. The aim is to increase the share of renewable energy to 38% by 2020 (see Table 2). For the first time, the strategy imposed a clear ceiling on Finland's energy consumption: energy consumption in 2020 must not exceed 310 TWh. New efficiency measures are therefore vital, as the target is 11% lower than the projections already made for energy consumption in 2020.

According to estimates produced by the Government, the share of electricity in final energy consumption will be up by 36% in 2050, while the need for fossil energy will fall by 24 TWh over the period 2005–2020 and by 104 TWh over the period 2020–2050, with the fossil energy need in 2050 being just 88 TWh [15]. The Government's target is that the need for fossil energy should fall by 11% by 2020.

The efficiency of electricity use should be raised to save about 5 TWh annually [17]. Characteristic of Finland's electricity consumption is the high proportion attributable to energy-intensive industries and the impact of heating and lighting demand over the long winter period. The country's electricity supplies will continue to be based on a distributed system that relies on a diversity and multiplicity of energy sources and is distributed because of the strong role of combined heat and power generation. In building Finland's own capacity, priority will be given to power plants that have no or low greenhouse gas emissions, such as combined heat and power plants using renewable fuels.

Table 2
Finnish Government's energy strategy, October 2008 [17].

	Year 2005 (TWh)	Year 2020 (TWh)	The growth rate (%)
Primary energy	381	430	12.9
Electricity			
Industry and building	44.2	56.0	26.7
Living	12.7	13.0	−9.1
Electric heating	8.8	8.0	8.7
Services	14.7	16.0	8.8
Other consumption	4.6	5.0	8.7
Total electricity	84.9	98.0	15.4
Other energy	216.7	212.0	−2.2
Final energy consumption	302.0	310.0	2.6
Renewable energy in final consumption	86.0	118.0	

Indeed, full implementation of the strategy referred to above would require a considerable increase in the share of domestic energy and especially renewable energy. The share of renewables in final energy consumption would rise to almost 40%, the efficiency of the energy system would improve and greenhouse gas emissions would be in permanent decline. The share of coal and oil on Finland's energy balance sheet would be decreasing too. The diversity of the energy system would further improve, and at the same time the risk of Finland's energy supply being jeopardised by energy crises beyond its borders would be reduced. The energy system would, to a certain extent, be based on greater use of electricity.

This strategy has also been criticised. The development scenario used as the basis for the calculations has, for instance, been criticised as being too ambitious [30]. Similarly, the target forecasts for energy and electricity consumption have been considered unrealistically high. Moreover, the strategy sets the energy efficiency improvement target at only 5% and its support for peat has been criticised as being unjustified. Neither does Finland's strategy include binding legislative means for reducing emissions, in contrast to the United Kingdom, for instance. Criticism has also focused on the fact that the strategy's emissions reduction target is 20%, even though the EU should be ready to raise the target to 30% in national climate agreements.

On the other hand, Finland's energy policy has drawn considerable praise in the International Energy Agency's (IEA) country review [31]. The IEA felt that Finland had devised sound and practical solutions in terms of energy security, environmental sustainability and economic competitiveness. The diversity of Finland's energy production was also praised as was its reliance on a variety of energy sources, with particular mention of nuclear power and the country's biomass and hydro resources. Key factors highlighted included Finland's successful decision-making, stable financing, strong national and regional research organisations, active international cooperation and the collaboration between public and private sectors. The IEA also declared its wish to see Finland give more attention in the future to strengthening long-term policy measures aimed at energy efficiency. It further recommended that Finland focus not only on the security of its imported energy supplies but also on the diversity of domestic energy production and on new renewable energy sources.

Despite the praise, the Finnish Government has not been able through tougher legislation to fully meet the energy challenges of climate change. Based on the measures in the Government's climate and energy strategy, domestic emissions reductions over the period 1990–2020 will most probably be less than 10% [22].

3. Factors driving change in the energy sector

Achieving a global energy policy is a challenge that requires extensive consideration of all the social, economic, political and environmental viewpoints. Consideration of global prosperity and wellbeing is increasingly relevant in studies of the energy sector. Climate change and energy issues, terrorism, disease epidemics, employment and other global concerns are all linked directly or indirectly to changes in the global economy. The growing uncertainty in the world and the increasing concern over environmental matters highlight the need for greater international cooperation to resolve problems. All these large-scale problems, including the urgent need for changes in the energy sector, are closely interrelated, with changes in one area affecting other areas either directly or indirectly [32].

3.1. Alarming scenarios

A highly regarded scenario study [33] indicates that the planet will not withstand the use of any more than a quarter of the known fossil energy resources that are economically exploitable with current technology. It therefore makes little sense to search for further oil reserves. The carbon dioxide budget for the first half of this century, 2000–2050, is approximately 1,000 billion tonnes (Gt), of which already almost one-third has been used during the first 9 years. The estimated volume of other gases that can be tolerated is about 500 Gt. Keeping within these limits would mean that there is a 75% probability that the temperature rise would remain below the two degree Celsius ceiling.

The scenario in question [33] also indicates that if emissions stay at current levels, the remaining room for manoeuvre will be used up in 20 years. However, if emissions continue to grow at the rate seen in recent years, the remaining amount of 'permissible emissions' would be used up a lot sooner—by about 2022, in the case of carbon dioxide. The opportunity to combat dangerous warming is still there, but in practice this means that emissions must start to decline within little more than 5 years from now. If emissions do not start to decline but instead grow only slowly over the next 10 years, the opportunities to avoid serious consequences after 2020 are considerably poorer.

The need for action is therefore very urgent. The trend in emissions over the next decade will largely determine whether the process of climate change can be kept at a moderate level [33]. If emissions do not start to decline rapidly, the proportion of 'permissible emissions' used up by 2020 would be so high that catastrophic warming could no longer be avoided.

According to the energy projections published by the VTT Technical Research Centre of Finland [34], which are rather more moderate than the scenario study referred to above, the 'deadline' for catastrophic warming would not be until 2050. The carbon dioxide emissions of the industrialised countries at that stage would then have to be very close to zero in order that a dangerous temperature rise above two degrees could be avoided. By 2050 there would also be a good understanding of how the world can produce energy in an environmentally sustainable way. The projections made assume that fossil fuels would still be used, but renewable energy use and energy efficiency would have to be dramatically increased, and use of electricity would need to be reduced significantly.

3.2. Oil price fluctuations

In the first half of 2008 the price of oil began to rise rapidly, and by the summer it had reached its peak of more than USD 150/barrel (in 12 months the price of carbon rose by over 75%). Then began a drop that was just as steep, and by January 2009 the barrel price had fallen to below USD 40. The drop was attributable to the signs of a slowdown in economic growth and a reduction in the demand for oil, and the shift of investors away from raw materials.

Changes in oil prices have an effect on all energy markets. The price of natural gas is tied to that of other fuels, especially oil, and to the price of electricity. Assessments made around the world of the future price of crude oil differ greatly. This is reflected in the strong uncertainty felt, and it also hampers the making of, e.g. assessments of improved efficiency in energy use stimulated through higher energy prices, of the substitution of some energy sources with other sources, and of the progress made with renewable energy.

Fluctuations in oil prices will affect national economies in different ways. In consumer countries, especially the United States, problems will arise from repeated peaks in oil prices. Changes in consumer habits have been causing considerable growth in oil consumption, not least because of rising living standards, industrialisation and car usage in China and India [31].

All 14 leading oil exporting countries are further developing their value chains by building petrochemical plants that will use a

growing percentage of domestic oil production [35]. All these countries, except for Norway, have doubled their domestic oil use since 2005. Studies suggest that in 2020 Russia could still be pumping 10 million barrels of oil a day. Domestic consumption within Russia will probably have risen to 5 million barrels, as compared with today's 3 million. Scaling these figures up, it is projected that in 2028 Russia's domestic consumption of oil will be 7 million barrels out of the 10 million barrels still being pumped daily.

High oil prices and other availability factors will have a radical impact on the energy sector throughout the world. It is also argued, however, that the recent peak in oil use has distorted the picture somewhat [35]. Emphasis, it is said, should instead be placed on the scope for developing new oil production methods. Even if the technology could be developed quickly, for instance regarding deep sea oil drilling and quarrying of sand and shale deposits, the existing oil production methods would probably retain their position for many years still.

Research on energy trends [36] has nevertheless shown that even with the growing influence of alternative energy production models, sales of oil will continue to grow considerably. Futures researchers also point out that, contrary to general conceptions, the world's oil reserves will not be running out in the short term. Calculations show that even at current levels of usage, OPEC could supply enough oil to meet 80% of the world's needs for at least the next 64 years.

3.3. Economic development and energy consumption intertwined

Future energy technologies are closely dependent on GDP growth and economic development. This has been studied in China, for example [37]. As economic development occurs, people demand more energy services to satisfy their ever growing comfort requirements at work and in their living environments. Energy consumption then rises as a consequence of this, unless the intensity of the additional use can be compensated by an increase in energy efficiency. The growing volume of office equipment in public buildings, for example, leads to an increase in the relative energy consumption per square metre, and energy use is forecast to grow at an ever faster pace. Energy consumption is boosted by factors such as brighter lighting systems, more sales outlets, use of heating thermostats and additional office supplies and equipment.

On the other hand, climate change and action to combat also affect GDP. The Stern Report [38] sparked an extensive debate on the costs of climate change for the global economy. A key conclusion of the report was that the benefits of tough and prompt action are considerably greater than the costs. Based on results from economic models, a decision to ignore the greenhouse effect would considerably reduce GDP by 2050 compared to a decision to take action. Put another way, early action to mitigate climate change will bring significant cost savings, whereas the upper limit of the costs of doing nothing is impossible to estimate with current knowledge.

The Stern Report has also been criticised. It is said, for instance, that the structural uncertainty surrounding global warming is just too great to be able to reduce everything to financial figures [39]. A wait-and-see approach has also been proposed, whereby climate policy would be gradually tightened as the problem worsens and as the economic situation in the world improves. It is argued that it is currently more productive to invest in physical and intellectual capital, including low emissions technology, than in direct emission reductions [40].

The dilemma of reducing energy use while promoting economic growth is acute. Emissions affecting climate change can in principle be reduced in two ways [41]: by altering consumption patterns and by introducing lower emission technological solutions for producing energy, products and services. However, at the same time governments are seeking to boost overall levels of consumption measured in terms of GDP. Growth, especially in developing countries, is nevertheless increasingly focused on sectors that consume less energy, for instance services, though there is almost no sector of any significance that is contracting in absolute terms.

The financial climate is creating not only pressure on the energy sector but also opportunities for the sector, and exploiting market mechanisms is an important part of effective climate policy. An economic downturn, it is said, is the right time for innovating to produce better and more energy-efficient products [42], not least because the underutilised resources at such a time should be harnessed more effectively to develop new ideas and to boost research. The profitability of energy-efficient systems will improve when they become mass-produced.

3.4. Change in consumer attitudes and values

The changeover to environmentally friendly energy solutions is inextricably linked to attitudes of decision-makers [16]. Consumers must be given the right advice on energy. This will help produce a change in attitudes, which will then translate into changes in actual behaviour. Armed with the right information, it will be easier to replace existing systems with new energy production alternatives [19].

People are only now truly understanding the contradictory nature of energy use: it nurtures, but it also threatens, the things we hold most dear, like our health, our homes, our children, the natural environment and the entire planet. The hopes and fears of consumers can give rise to a range of different responses in the energy arena [43].

Green attitudes today are on the increase [14], though a distinct difference in the nature of responses can be detected: many people adopt green habits (including energy saving) that are easy and convenient, and relatively minor, while others believe in more radical steps. Social considerations, i.e. following what others do or do not do, are probably an important reason why many people are not taking more active steps to influence energy issues. It is easy to assume the role of bystander when faced with the complexities of the climate problem. The consequence of this, at worst, is that all participants, including political decision-makers, stay rooted to the spot, waiting for the solution to arrive from somewhere else [44].

4. Priorities for future energy policies

The entire energy production system will experience a considerable upheaval in the coming years. The demand for new energy technologies and for more efficient energy use is great. A lot is expected of the new opportunities offered by the nano-bio sector and micro- and nano-chemicalisation. Indeed, technology is likely to play a very key role in emissions reduction. This will require considerable investment in developing efficient and low-emission technologies for producing and using energy, and in efficiently bringing these to the market [45].

The acclaimed Energy Technology Perspectives report [46] states that almost half of all emissions reductions is likely to be achieved through more efficient end-use of energy. If a considerable reduction in greenhouse gas emissions is to be achieved, this will require that the annual investment of hundreds of billions of Euros currently made in fossil-fuel energy technologies is switched gradually to new, efficient, low-emission technologies and to improvements in the efficiency of energy use. In addition to these new technologies and nuclear power, results indicated that carbon capture and storage technology (CCS) will be a significant emissions reducing tool [47]. The introduction of emissions

reducing technologies will be slowed by the costs and by the time lags involved in renewing investments.

Having studied the issues, the Confederation of Finnish Industries has drawn up its own list of positive changes it feels are needed in the business environment and which should be acted on without delay, presented under six main headings [48]:

- Diversity of energy sources: all energy production alternatives must be available, including nuclear power.
- Highly efficient energy production, transmission and use: energy efficiency agreements.
- Renewable energy cost-effectively: supply of renewable energy must be secured at a competitive price.
- Productive and efficient policies and measures: ambiguous or conflicting measures must be avoided.
- Energy technologies and innovations: strategic concentration of top expertise, especially on energy and climate.
- Combating global climate change: equal operating conditions must be secured for all companies.

Research has concluded that the most important changes necessary in the energy system in Finland are as follows [27]: increase in the use of renewable energy sources, nuclear power and afforestation, the latter having proved effective for Finnish circumstances. Development work should focus on carbon capture and storage (CCS) technology, as it is felt that this will be significant in the future. In CCS technology, the carbon dioxide content of emissions is captured and stored, for instance in storage facilities below ground or under the sea. Commercially exploitable technology for capturing carbon dioxide from large sources of emissions already exists, but the problem of storing the carbon dioxide has not yet been resolved. An increase in operating efficiency is desirable, but the goals must be carefully specified in order that the profitability of investment in technological solutions can be properly assessed.

Many different attempts have been made to model the key elements of energy and climate policy. Realistic energy strategies are called for in order that global cooperation can proceed effectively [37]. Changes are happening slowly, as there is little desire to give up benefits to which contemporary society has become accustomed. To implement changes, however, it will be necessary to accept the economic realities and the indirect costs, and political commitment will be needed. For energy strategies to produce results they must be fair and based on statutory regulation. Various combinations of energy solutions are called for, and if high efficiency and cost-effectiveness are to be achieved, the policies and measures must be clear and justified. Future opportunities clearly exist for ensuring a diversity of energy sources and developing innovative technologies.

Mitigating climate change is the common goal of the energy strategies of all countries. Fig. 1 illustrates the factors that motivate and the factors that deter such actions. It also shows the steps that should be taken immediately and those that will require action in the future.

5. Pressure for changes in Finland's energy policy

International trends and events have an impact on Finland, helping to create the framework for national action. Without doubt the most important international player from Finland's viewpoint is the European Union, which has considerably strengthened its role in energy policy issues.

An extensive study of the economic and environmental capacity and potential of renewable energy systems over the next 30 years was recently concluded under the Distributed Energy Systems Technology (DENSY) Programme 2003–2007, coordinated by the Finnish Funding Agency for Technology [49]. A large share of the potential market for distributed energy systems lies in the developing countries, with their underdeveloped infrastructure. Tight regulation and technologically advanced systems are difficult in such conditions, however. Exporting technologically advanced systems to such 'uncontrolled' markets would approach the study's 'green paradise' scenario.

The results of the DENSY project [49] nevertheless indicate that an incentive-based scenario would be the best from Finland's viewpoint. Under such a scenario the energy infrastructure would be based on tight regulation backed up by an international system of sanctions. In an incentive-based scenario:

- The government controls the market by means of legislation and creates incentives for using new forms of energy production.
- Business opportunities are actively developed.

Efforts have been made to separate the efficiency viewpoint from that of energy and environment. With energy prices rising, all forms of energy use will be required to be as efficient as possible. Regulation will also create its own pressures, as it will restrict certain activities, but on the other hand it will also offer new global

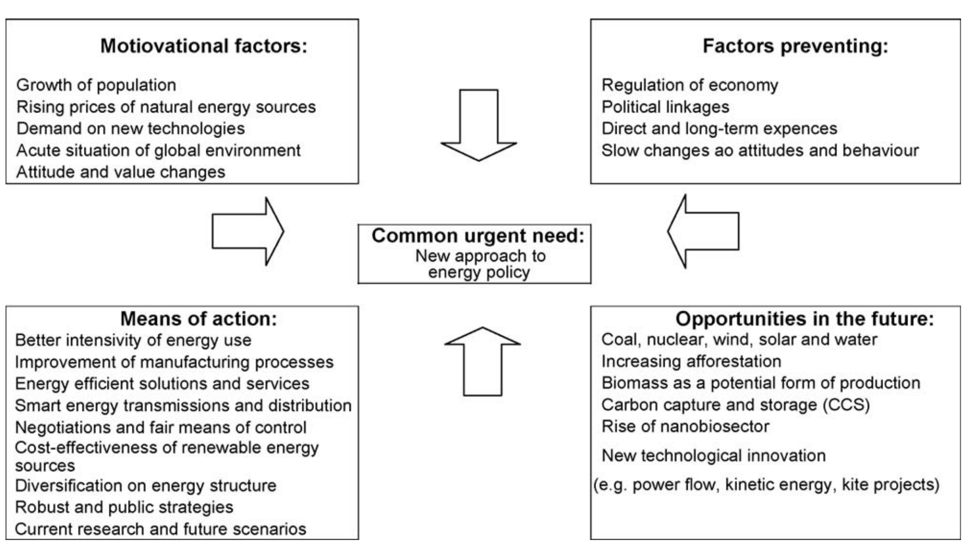

Fig. 1. Aim of mitigating climate change: motivating factors, deterrent factors, immediate action and possible future action.

business opportunities for fast, change-responsive players and for breakthrough technologies created by them.

The strategic elements of Finland's energy cluster, encompassing considerations of efficiency, economy, environment and human wellbeing, are as follows [49]:

- Equipment and systems for clean energy production: tools and processes that enable energy production and distribution in as environmentally friendly a way as possible.
- Emission-free processes: aim at zero emissions, even when using fossil fuels.
- Energy-efficient solutions and services: modes and models of operation that enable energy-saving production.
- Environmentally friendly production and products: based on limited resource use, energy saving, recycling and a lifecycle approach.
- Solutions for sustainable use of raw materials: manufacturing and processing technologies with which raw material use can be reduced and detrimental effects of use minimised.
- Smart energy use and distribution: making use of new ICT solutions that combine security of supply, energy saving and environmental friendliness.

Distributed energy production is closely tied to the use of renewable energy sources. Renewable energy sources, such as wind, solar and wave power as well as biomass, are generally geographically distributed in such a way that there are no major energy densities offered in any one place, and transportation of the primary energy raw material is usually not practical. Changes in the operating environment of the energy sector have typically been slow and plagued by inflexibilities [49]. There are fundamental barriers in Finland to the commercial development of new systems for distributed energy production. The country has a high concentration of energy-intensive heavy industries, and its basic energy production solutions are built around centralised production. Nuclear power solutions and the fairly widespread use of combined heat and power production have allowed the price of electricity to be kept low, which has meant that investment in distributed energy systems is not feasible without massive subsidies. The possibility of connecting distributed energy production with the power grid on a flexible basis is essential for the development of the sector.

Demands for expanding the use of renewable energy sources in Finland have not led to the kind of pressure for distributed systems that has occurred in other countries. A contributing factor here is that in Finland, the proportion of energy produced using renewable energy sources is high by international standards. This is largely due to the forest industry. However, in other renewable energy sources, such as wind power, solar power and biogas, Finland is only a small player. In addition, Finland and Malta are the only EU countries that do not operate feed-in tariff systems for supporting the use of renewable energy sources. (Finland's Ministry of Employment and the Economy is currently preparing proposals on the structure and scale of a feed-in tariff system, with the aim of introducing such a system in Finland.) Feed-in tariffs are state-funded support for energy production in cases where costs exceed the market price. In Finland, a lot of work has been done to increase the share of renewable energy forms [50], and this share is already high despite the fact that the exploitation of many renewable energy sources is more costly in Finland than in other countries.

At the start of 2008 the Finnish Government took the decision to grant installation-specific emission rights for 2008–2012. Emission rights were granted to more than 500 installations [25]. The strength of this emissions trading system is that it creates a price for carbon. There are weaknesses too, however, which lie in the gratuitous distribution of emission rights and carbon leakage and windfall gains. The opportunity created by the emissions trading system is that the competitiveness of low-emission and emission-free energy production will grow. The threat, on the other hand, is that greenhouse gas emissions will not fall globally, and that carbon will 'leak' from Europe to places outside the emissions trading system.

In terms of energy supplies, Finland is nevertheless well placed, in that the most significant energy forms all have a similar share of the market. When no energy form has a dominant status, there is less dependence on any single energy source and the risk of an energy crisis is therefore much less. Finland nonetheless imports an increasing amount of natural resources in the form of raw materials and products from abroad. Energy production and consumption thus have local and regional environmental implications beyond Finland's national borders. Finland is to a large extent reliant on imports, as only one-third of its energy is from domestic sources [29]. Increasing attention has been focused on problems concerning imports, especially in the debate on biofuel imports. Other imports too can be associated with significant environmental effects in their countries of origin [17].

The Finnish Government's publicly declared position is that the focus of future energy policy will shift increasingly to renewable energy forms. Most significant among these are wind and hydro power, biomass, solar energy and geothermal energy. Studies at national level show that biomass and wind have considerable potential as future energy solutions [34]. Peat is an interesting prospect, though there are also good opportunities for the increased use of conventional and enhanced geothermal energy. The greatest potential is considered to be in forest energy, wind power, field biomass and recycled fuels, though not forgetting biogas, geothermal and small-scale hydro power. There are plans to accelerate the uptake of renewable energy sources through various means, such as investment grants, the imminent feed-in tariff systems and certificates [17].

Various scenarios for the period to 2050 have been modelled for cost-effectively reducing Finland's greenhouse gas emissions [43]. The cost of emission rights is expected to grow dramatically from its current level, which is about EUR 10 per tonne of carbon dioxide. Studies indicate that greenhouse gas emissions in Finland could be reduced by more than 60% from the 1990 level by 2050, provided the price of emission rights does not exceed EUR 80 per tonne of carbon dioxide. This price level was selected on the basis of other analyses, which found that this could be a realistic level in international emissions trading by 2050 [27]. It also follows that if emissions reduction targets for Finland were to be even tighter than this, purchasing emission rights would become a more attractive option than engaging in the domestic action to reduce emissions.

In Finland, the most important technologies for reducing emissions will be bioenergy, nuclear power and wind power. Studies indicate that solar energy will still occupy only a marginal position, at least as far as electricity generation is concerned. However, solar heating, by contrast, has potential for heating buildings. According to the scenario study results, a major increase in the construction of nuclear power facilities will not significantly reduce the emissions level achievable by 2050 [43]. It would, however, significantly reduce the costs of emission restrictions and could also reduce the market price of electricity to a significant extent. The scenarios in which nuclear power is expanded in the longer term nevertheless contain considerable uncertainty in regard to developments in technology and political decisions. Another significant uncertainty in the results is the realistic potential and costs of carbon capture and storage (CCS) technology in Finland. Despite this, the role of CCS technology in reducing emissions was quite considerable in the scenarios, even with the prices of emission rights set at their highest.

With low-emission forms of energy production, it is possible to decrease the costs of greenhouse gas emissions reduction, to reduce sulphur, nitrous oxide and particulate emissions, to lessen the dependence on imported electricity and to reduce the uncertainty caused by the rise in fossil-fuel costs. Energy saving and the efficiency of energy use are, however, essential alongside production efficiency: if the current wasteful use of energy cannot be limited effectively all over the world, none of the low-emission energy production technologies likely to be available in the coming decades would be enough to curb emissions by the extent required. Consumption habits will have to change considerably.

Finland's energy system is efficient, which means that the scope for increasing efficiency is comparatively small [51]. The long-term scenario calculations support this view, since in any imposition of a 50% cut in domestic emissions by 2050, only 40% of the required emissions reduction would occur through energy-saving measures, fuel-source changes and various technological advances in energy production and use. About 60% of the changes would occur through carbon capture from power plant exhaust gases and by a wholesale change in the motive power of vehicles in the transport system. The large-scale adoption of both of these measures still requires considerable development work.

In futures studies, even more radical estimates have been discussed. According to the results of the VTT Technical Research Centre of Finland, the country could reduce its greenhouse gas emissions by 60% or even more by 2050 from the 1990 level [52]. The calculations show that this could be achieved if emissions restricting measures were to be introduced up to a cost level of EUR 80 per tonne of carbon dioxide equivalent by the year 2050.

The results of an extensive study looking at the demand for energy technology and the international business opportunities in Finland as the country's climate policy evolves (the SETELI study), indicate that future climate policy must act as a driving force in the energy technology markets [27]. It is interesting too that the project's results suggest that the EU's two degree goal will require that greenhouse gas emissions are reduced to about one-third of their current level. There will naturally be a huge market for low-emission and energy-efficient technologies, on account of the need to mitigate climate change, but also due to rising energy prices. This trend will be most rapid in the developing and emerging countries, where growth in energy consumption is fastest and the infrastructure still at a development stage.

6. Conclusions

The global situation regarding the climate has reached a point where very urgent action is required. The energy policy of Finland and of all other countries must therefore be refocused on combating climate change. The scale of the problems and the potentially catastrophic consequences are no longer questioned. If emissions do not start to decline rapidly, so much of the remaining capacity to produce emissions would be used up by 2020 that catastrophic warming could no longer be avoided.

The factors driving change in the energy sector will set in motion a wide range of different impact chains. Dramatic fluctuations in oil prices in particular will have a considerable impact on the sector. Unforeseeable changes in oil production and prices add to the uncertainty, especially among consumers. Economic development and energy consumption are inextricably linked to each other, in that GDP growth increases consumer demands for comfort and convenience and also influences future energy technologies. Changes in consumer attitudes and values will have a strong impact on the energy sector.

The need for global cooperation is also growing, the common goal being to urgently curb climate change. The means already exist and should be harnessed for use without delay, though there are factors that motivate this and factors that deter this. Resources must also be directed at developing new policies and measures for the future. This must recognise the following four key considerations.

Firstly, the motivating factor for action to mitigate climate change is the acute state of the global environment. Populations and economies are growing, thus generating further demand, also for new technologies. The prices of exhaustible natural resources are rising and the values and attitudes of consumers are changing.

Secondly, factors deterring action are the direct costs and the long-term costs. Political and economic decisions will prevent any radical moves. On the other hand, changes in consumer behaviour will first require changes in attitudes, though these tend to change only slowly.

Thirdly, the existing means for acting should be urgently adopted: diversification of the energy sector to focus more on renewable energy; a significant increase in the efficiency of energy use; improvements in processes for manufacturing raw materials; smart energy transmission and distribution; energy-efficient solutions in services; and an expansion in afforestation. The cost-effectiveness of renewable energy sources must be considered, clear and publicly declared energy strategies must be incorporated in legislation and productive and fair policies and measures developed for them. Use must be made of the latest research results and the results of futures scenarios.

Fourthly, resources must be directed into developing potential tools and methods for future use. The energy sector must also exploit the potential of nuclear energy, wind, solar and hydro power, biomass, carbon capture and storage (CCS) and the nano-bio sector. Biomass, CCS and the nano-bio sector are all emerging alternatives with potential. Completely new technological innovations are also needed.

A number of interesting and challenging areas for further research are highlighted as a result of this literature review. In particular, up-to-date information on people's continuously changing values and attitudes is needed. It would be beneficial to study different age groups and sections of the population separately, and to compare the effect of background factors on people's attitudes to energy issues. Further areas of interest include the connections between slowly changing consumer attitudes and the behaviour of consumers, and a more rigorous examination of the relationship between the energy sector and environmental and economic issues, comparing recent with past trends. New perspectives could also be introduced into the study of futures scenarios, and it would be useful to review the accuracy of previous forecasts and the causes and effects at play. It is also essential that further research is conducted on the effectiveness of existing and potential future actions.

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